UK Resonant Cavity Magnetron Development

Mark Oliphant's group at Birmingham University was set up in the latter part of 1939 with the main remit of producing a high power generator of centimetre waves which it was known would be required for the creation of effective airborne AI and ASV radar. It is surprising that in view of the amount of RCM information in the public domain that no initial effort was put into evaluating magnetron performance as a means of achieving this objective. Instead most work was concentrated on increasing the power of the klystron which had been invented by the Varian brothers in 1938.

John Randall and Harry Boot joined the Birmingham group several weeks after it was first set up. They had spent some time at the Ventnor long wave (CH) radar station assessing radar systems in general. When they joined the Birmingham group most of the interesting projects had already been allocated and they were given the task of evaluating Barkhausen–Kurz oscillators which they soon concluded would not yield the sort of power levels being sought.

Accordingly they decided to investigate the magnetron approach and constructed their prototype with a 6 resonator copper block anode. John Randall claimed he had no previous magnetron knowledge, although in a letter written in 1984 shortly before his death he acknowledges that they were aware of the magnetron due to the previous work at GEC, Germany and the USA. However Randall's work prior to joining the group had been research into phosphors for fluorescent lamps so his comment in the same letter that the idea of a cavity resonator came to him as a result of reading a copy of an English translation of Hertz's "Electric Waves" seems entirely believable.

Due to the lack of equipment at Birmingham, before the prototype magnetron could be tested the team had to make their own high voltage rectifiers, borrow a high voltage transformer from the Admiralty and make use of an old Biot electromagnet to provide the magnetic field. Finally on the 21st February 1940 all was ready and the prototype magnetron was powered up for the first time whilst still "on the pump".

They were surprised to see streams of high frequency radiation emitted from the output probe and successively higher powered car headlamp bulbs were being burnt out when connected as a load. They had difficulty in believing the RF output was in the microwave region. The next day the wavelength was measured using Lecher wires and the wavelength was found to be 9.8 cms and the power output estimated at 400 Watts CW.

The significant difference between the Randall & Boot RCM and those previously patented was that all the others (barring perhaps the Russian one) had their anode system inside a glass envelope containing a vacuum whereas the Birmingham valve had its vacuum system inside the anode structure. Not only did this allow for much more efficient cooling of the anode system and therefore higher dissipation, but in general it allowed for a smaller air gap in the magnetic path.

The Birmingham prototype was passed to E.C.S. Megaw's group at GEC Wembley and they very soon produced a pre-production design the E1188. This device still had a filamentary cathode and was therefore not ideal for pulse operation.

About this time (May 1940) some examples of the French M16 16 cms multi-segment anode magnetron, which had been developed for the collision avoidance radar fitted to the liner Normandie, were brought to Wembley by M. Maurice Ponte of SFR. One of these M16 had an indirectly heated oxide coated cathode and this was incorporated within a revised E1188 design and designated E1189.

The initial samples of the E1189 still used the 6 resonator anode block which had been drilled using the chamber of a Colt revolver as the drilling jig. However examples No. 11 and 12 had the number of resonators increased to 8 in order to maximise the efficiency of the valve with the magnetic field provided by the then available permanent magnet, E1189 also incorporated cooling fins to enable the device to be air rather than water cooled. Sample No.12 was taken to the USA by E. Bowen with the Tizard mission and upon testing at Bell Labs produced 10 times the power at 5 times the frequency of the best performing American triodes. A certain amount of confusion arose as the drawings taken by Bowen still showed the 6 resonator anode but an X-Ray picture taken at Bell Labs revealed the presence of 8 resonators.

The E1189 or its Navy equivalent NT98 was used in the Naval radar type 271 which was the Allies first operational centimetric radar.

The early RCM's like the E1189 were prone to mode jumping (frequency instability) under pulse conditions and the problem was solved in by means of strapping together alternate segments a process invented by Sayers in 1942. Strapping also considerably increased the magnetron's efficiency.